Scattering: Seeing the Microscopic Among the Giants
A Cassini Science Investigation

Purpose
Light waves passing through a medium are used to determine the sizes of particles within the medium.

Saturn System Analogy: Rings

Keywords: Scattering, Shadow, Obscuration

Our everyday view of the world relies on the reflection of light from the objects around us. This reflection is called backscatter, especially when applied to tiny objects scattering light back to an observer when the light source is behind him or her. Very tiny objects, approximately the size of the source wavelength, also send light forward. This light travels in approximately the same direction of travel as it came from the source, more efficiently than they backscatter light. This effect, called forward scattering, is used by scientists when studying planetary atmospheres and ring systems. The scattering helps to determine the sizes of particles in those environments.

Materials
- Laser pointer
- Two large binder clips
- Two clear, plastic or glass water bottles or cups (walls should be vertical), 50-100 mm in diameter (bottled water or soft drink bottles are good as long as they have some non-corrugated surface)
- Tap water
- Milk (1/20 tsp - a “pinch” per 12 oz. of water)
- Eye dropper
- Flour (less than or equal to 1/4 tsp. per 12 oz. of water)
- Lazy Susan (optional but helpful)
- Masking, duct, or electrical tape

Procedure
Adhere a piece of tape to one side of the container. Fill the first container with water and place it on the lazy Susan. Prepare a highly dilute solution of milk, thoroughly mixed so the water is just slightly whitened. (Find the right proportions by experimentation in advance.)

For convenience, use the binder clips as legs to stand the laser, with one also holding the laser's switch in the “on” position.

Align the laser to pass through the water container so the beam projects onto the small piece of opaque tape on the far side of the water container. (The tape is to prevent the laser beam from being projected across the room into viewers' eyes.)

Darken the room, if possible. Project the laser beam through the container of plain water. The beam should pass straight through and be invisible or nearly so. Next, project the beam through the dilute milk solution. Laser light scattering from tiny particles of milk will delineate the laser beam. Observe the brightness of the beam in the mixture as the lazy Susan is rotated. The intensity of the beam is stronger or weaker according to the scattering properties of the milk particles (primarily their size) as the assembly is turned in front of fixed observers. For older students, a simple photometer can be used to compare the brightness of the beam as a function of the viewing angle. Note how the beam reaches maximum brightness when looking in nearly the direction it is coming from.

Next, mix flour with the plain water (less than or equal to 1/4 tsp flour per 12 oz of water) in the first container. Project the laser beam through the dilute flour solution. The scattering properties of the milk and flour solutions are different because there is greater variation in flour particle size than in milk particle size. Recall that store-bought milk is homogenized (its particles are reduced to the same size) so the cream stays in the solution. With either mixture, notice how the beam intensity diminishes with distance (looking from the side).

As a an everyday, terrestrial example, recall that bright headlights in fog may or may not help drivers, depending on particle size. Backscatter from large fog droplets makes night visibility with bright headlights pooer than with dimmed headlights.

Additional Experiments and Questions

Try other materials that will remain suspended in liquid for useful amounts of time. Corn meal, corn starch, silt from a local stream bed, glitter, salt, and sugar will provide varying results. Try transparent carbonated beverages, including their foams, and cigarette smoke trapped in a jar. Which work? Which don't? Why? Can you detect different particle shapes based on scattering?

Is the color of the daylight sky related to sunset colors and scattering?

Because scattering is a phenomenon dependent on both the wavelength of the wave being scattered and on the size of the scatterer, much can be learned by working in well-separated parts of the electromagnetic spectrum. Where light waves tell us about the sizes of small particles, radio waves can tell us about the sizes of objects ranging in size from golf balls to houses.

Science Standards

A visit to the URL http://www.mcrel.org yielded the following standards and included benchmarks that may be applicable to this activity.

10. Understands basic concepts about the structure and properties of matter.

Level I: Primary (Grades K-2)

Knows that different objects are made up of many different types of materials (e.g., cloth, paper, wood, metal) and have many different observable properties (e.g., color, size, shape, weight).
Knows that things can be done to materials to change some of their properties (e.g., heating, freezing, mixing, cutting, dissolving, bending), but not all materials respond the same way to what is done to them.

Level II: Upper Elementary (Grades 3-5)
Knows that objects can be classified according to their properties (e.g., magnetism, conductivity, density, solubility).
Knows that materials may be composed of parts that are too small to be seen without magnification.

15. Understands the nature of scientific inquiry.

Level I: Primary (Grades K-2)
Knows that learning can come from careful observations and simple experiments.

Level II: Upper Elementary (Grades 3-5)
Knows that scientific investigations involve asking and answering a question and comparing the answer to what scientists already know about the world.
Knows that scientists use different kinds of investigations (e.g., naturalistic observation of things or events, data collection, controlled experiments), depending on the questions they are trying to answer.
Plans and conducts simple investigations (e.g., makes systematic observations, conducts simple experiments to answer questions).

Level III: Middle School/Jr. High (Grades 6-8)
Establishes relationships based on evidence and logical argument (e.g., provides causes for effects).

Level IV: High School (Grades 9-12)
Knows that a wide range of natural occurrences may be observed to discern patterns when conditions of an investigation cannot be controlled.

Scattering Student Sheet

Procedure

Your teacher will set up the experiment.

- The teacher will shine the laser through a glass of water. What do you see as the glass is rotated?
- The teacher will then add milk, flour, or some other substance. How does the laser beam change as it passes through the water mixture?
- The teacher will experiment with different substances in the water. Observe how the beam changes as each different material is used.

Questions

- What are some examples of light scattering in everyday life?
- Which materials work well? Which don't?